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ABSTRACT

A model of conceptual learning and development that provides a framework for studying the course of cognitive development throughout the school years and also studying the learning concepts across short time intervals is discussed in this paper. The theory includes five main propositions. First, children learn four successively higher levels of the same concept in an invariant sequence. The four levels are designated concrete, identity, classificatory, and formal. The rates at which individuals attain the successive levels vary and not all individuals attain the formal level of many concepts. Also, the age at which the individual attains a certain level varies among concepts. Results of factor analytic studies examining the relationship between the structure of cognitive and educational development are presented. The present set of studies indicates that scales can be constructed to measure the course of cognitive development, based directly on a theory that specifies the mental operations required to attain successive levels of the same concept and also the uses that individuals can make of the concepts they have learned. (Author/AM)

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The Abilities Underlying Educational Development and Concept Achievement[1]

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The study of cognitive development deals with the orderly progressive changes that occur, from birth to maturity, in the cognitive structure and abilities of individuals and in their related observable and inferrable behaviors. We may regard the cognitive structure as all the raw perceptual information, facts, concepts, principles, theories, and strategies for learning and doing that the individuals have about themselves and their environments. The cognitive structure of the individual changes from birth onward as a product of learning and maturation, or more broadly of development. Understanding the relationship between cognitive development and educational development and identifying the abilities that may underlie these developments during the school years is of interest to theorists, practitioners, and educational policy makers.

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[2]Based on paper presented at a symposium, "Intelligence and Performance: Newer Conceptualizations and Relevance for Behavioral Measures of Success," at the 1976 annual meeting of the American Association for the Advancement of Science, Boston, Massachusetts.

[3]The author thanks Patricia S. Allen for reading this paper and providing many helpful comments.

My research activities and those of my successive project staffs[4] have been directed toward understanding cognitive development during the school years and identifying the instructional conditions that facilitate the learning of concepts, principles, and problem-solving techniques (Klausmeier, Harris, & Wiersma, 1964; Klausmeier, Harris, Davis, Schwenn, & Frayer, 1968). In 1972 we started a four-year longitudinal study to chart the course of cognitive development in school children, age 5 to 18 (Klausmeier, Sipple, & Allen, 1974a; Klausmeier, Sipple, & Allen, 1974b; Klausmeier, Allen, Sipple, & White, 1976a; Klausmeier, Allen, Sipple, & White, 1976b; Klausmeier, Sipple, Allen, & White, 1976) and have also carried out preliminary factor analytic studies to relate cognitive development and educational development. A model of conceptual learning and development has been formulated that guides these research activities (Klausmeier, 1971; Klausmeier, Ghatala, & Frayer, 1974). Understanding the main features of this theory will be helpful in dealing with the factor analytic studies to be summarized later.

A Model of Conceptual Learning and Development

An analytic, descriptive model of conceptual learning and development as outlined in Figure 1 was formulated. It provides a

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[4]The group in 1975-76 includes Patricia S. Allen, assistant scientist; Thomas Sipple and Keith White, project specialists; and graduate students Kay Bull, Gregory Mize, Joan Schilling, and James Swanson.

Insert Figure 1 about here

framework for studying the course of cognitive development throughout the school years and also studying the learning of concepts across short time intervals (Klausmeier, 1971; Klausmeier, Ghatala, & Frayer, 1974). We are attempting to identify what is represented in the cognitive structure successively across the developmental years, the mental operations involved in learning it, and the instructional conditions that facilitate the learning. The theory includes five main propositions. First, children learn four successively higher levels of the same concepts in an invariant sequence. The four levels are designated concrete, identity, classificatory, and formal. The rates at which individuals attain the successive levels vary and not all individuals attain the formal level of many concepts. Also, the age at which the individual attains a certain level varies among concepts.

Second, certain internal conditions stated as mental operations are prerequisite for attaining each given level. One or more new operations are involved at each successively higher level. These new higher level operations are presumed to emerge as a product of learning and biological maturation, or more broadly, of development. The attainment of any given concept at each successively higher level is explained, not as an additive reception process, but as a qualitatively different construction process.

Third, concepts when attained at the successively higher levels are used more effectively in understanding principles of which the concept is a part, in understanding taxonomic and hierarchical relationships of which the concept is a part, and in solving problems involving the concept.

Fourth, having the name of given concepts and of their defining attributes facilitates the learning of the concepts at the concrete, identity, and classificatory levels and is essential for learning concepts at the formal level.

Fifth, the external conditions that facilitate attainment of each level differ according to the levels and are necessarily directed toward utilization of the operations essential for attaining the particular level (Klausmeier, in press; Klausmeier, Ghatala, & Frayer, 1974).

The proposition that a concept is attained at the four successive levels applies only to those concepts that: (a) have more than one example, (b) have observable examples or representations of examples that are observable, and (c) are defined in terms of attributes. Not all concepts are of this kind. Some concepts have only one example, e.g., the earth's moon. Some do not have observable examples, e.g., atom, eternity, soul. Still others are defined in terms of a single dimension; e.g., rough, thin, or in terms of a relationship, e.g., south, between, above. Some of the four levels are, however, applicable to these kinds of concepts also. For

example, the identity level is applicable to concepts that have either one example or identical examples; the classificatory level is applicable to concepts that have either one example or identical examples; the classificatory level is applicable to concepts of only one dimension or that express a relationship; and the formal level is to those concepts that have no observable, classifiable examples. The concepts used in our longitudinal study necessarily meet the criteria as stated in (a), (b), and (c), since we are interested in children's short-term learning and long-term development of the same concepts, kindergarten through high school. One cannot readily study concept learning or development in young children using concepts that have no observable examples. Also, to determine whether or not students have attained concepts at the formal level one must also use concepts, the definitions of which are agreed upon, so that students' performances can be judged as acceptable or unacceptable.

With this introduction to the four levels and the three uses of concepts, the mental operations pertaining to each level are discussed. Tests have been constructed to measure the levels as presented.

Concrete Level

Attaining a concept at the concrete level is inferred when the individual recognizes an object that has been encountered on a prior occasion. The operations involved in attaining this level are attending to an object, discriminating it from other objects,

representing it internally as an image or trace, and maintaining the representation, or remembering it.

Identity Level

Attainment of a concept at the identity level is inferred when the individual recognizes an object as the same one previously encountered when the object is observed from a different spatio-temporal perspective or sensed in a different modality, such as hearing or seeing. The operations of attending, discriminating, and remembering are involved in attainment at the identity level as they also are at the concrete level. Generalizing is the new operation postulated to emerge as a result of learning and maturation that makes attainment at the identity level possible.

Some psychologists (e.g., Gagné, 1970) treat concepts at the concrete and identity level as discriminations. Piaget (1970) refers to them as object concepts. The critical matter is not what they are called, but to explain the internal and external conditions of concept learning at these two lowest levels.

Classificatory Level

The lowest level of attaining a concept at the classificatory level is inferred when the individual responds to at least two different examples of the same class of objects, events, or actions as equivalent. Individuals are still at the classificatory level when they can correctly classify a large number of instances as examples and others as nonexamples but they cannot define the word that represents the concept and also cannot explain the basis of their

classifying in terms of the defining attributes of the concept. At this higher phase in attaining concepts at the classificatory level, children seem to be able to discriminate some of the less obvious attributes of the concepts and to generalize correctly to a great variety of examples, some of which are very much like some non-examples. Also they seem to be able to make more explicit than they did earlier the basis of their classifying. In terms of Kofsky's (1966) analysis, included from the beginning to the end of the classificatory level as described here is the following classificatory acquisition sequence of Inhelder and Piaget (1964): consistent sorting, exhaustive sorting, conservation of classes, knowledge of multiple-class membership, horizontal classification, and possibly hierarchical classification.

Formal Level

Attainment of a concept at the formal level is inferred when the individual can give the name of the concept, can define the concept in terms of its defining attributes, can discriminate and name its defining attributes, and can evaluate actual or verbally described examples and nonexamples of the particular concept in terms of the presence or absence of the defining attributes. When individuals can do these things it may be inferred that they are also capable of performing the operations for the formal level.

There are two patterns of inductive operations. One pattern involves formulating and evaluating hypotheses regarding the

attributes of the concept and the other involves cognizing the attributes that are common to the positive instances. The commonality approach is used more often than the hypothesizing approach by young children apparently because they are either incapable of getting information from the available nonexamples or they cannot carry out the hypothesizing and evaluating operations (Tagatz, 1967).

Learning a concept at the formal level deductively when given all the essential information entails meaningful reception learning as described by Ausubel (1968). Information is assimilated, remembered, and then can be used later in identifying examples and nonexamples of the concept. Much concept learning at the formal level by upper elementary (age 10-12), high school, and college students follows this pattern. In this kind of expository instruction, students are given the name of the concept, a verbal definition, verbal or pictorial examples, and verbal or pictorial nonexamples but usually no actual instances of the concepts.

Before leaving this section, a few words should be said about acquiring the names of concepts and their attributes and the role of language in concept learning. The important role of language in concept learning is made clear by Bruner (1964) and Vygotsky (1962). McNeill (1970) provides an extensive review of research and theory regarding the interaction of language development and conceptual development. Our analysis of research (Klausmeier, Ghatala, & Frayer, 1974) led to two major conclusions regarding the relationship

between aspects of language acquisition and concept attainment. First, having the names of the concept and of its defining attributes is not essential for concept attainment at the concrete, identity, and classificatory level. However, having the names, or other signs and symbols that take the place of names, is essential for attainment at the formal level. Generating hypotheses and evaluating hypotheses, two mental operations at the formal level, require the use of the labels for the concept and its defining attributes.

A Hierarchical Structure of Cognitive Development--Educational Development

If we have identified the four levels of conceptual development correctly, and if the mental operations essential for mastery of these particular concepts generalize to other concepts in the same subject fields, then scores of the levels tests from the assessment batteries should be highly correlated with the uses of the same concept, the achievement of other concepts in the same subject fields, and also with scores on educational achievement tests in the same subject fields, provided the educational achievement tests measure understanding of concepts and principles rather than the recall of information. To test this line of reasoning, a doctoral study (Rampaul, 1976) was conducted in which 100 fourth-grade children and 102 seventh-grade children were administered 35 and 33 tests, respectively. (Tabular and graphical data are presented only for the seventh-grade children because of space limitations; the names

of the 33 tests to be discussed appear later in Table 1.) For each of the three assessment batteries, equilateral triangle, noun, and tree, one levels score for the combined four levels and one uses score for the combined three uses were derived, a total of six scores. Twenty-one concept-achievement tests were also administered, seven in each of the three subject areas, mathematics, English, and science. Each of these concept-achievement tests measured understanding of a different concept that the students presumably had had an opportunity to learn. Four standardized educational achievement tests from the Stanford Achievement Tests were administered to the grade 4 children: word meaning, capitalization, arithmetic concepts, and science; the grade 7 children were administered capitalization, arithmetic concepts, and science. Four cognitive ability tests were also administered to the fourth-grade students: class name selecting, verbal classification, figure exclusion, and circle reasoning; the first three but not the last one were administered to the seventh-grade students. These were presumed to measure specific classification skills of the kind included at the classificatory level of the assessment batteries but these tests had not been used in prior studies.

Correlations were obtained for each grade and unrotated and rotated factor solutions were obtained using the alpha procedure (Kaiser & Caffrey, 1965), Harris R-S^2 (Harris, 1962), Unrestricted Maximum Likelihood Factor Analysis (UMFLA) (Joreskog, 1967; Harris & Harris, 1973). Close correspondence of results was found by these

different procedures, and the results accounting for the most variance were obtained from the Unrestricted Maximum Likelihood analysis.

At both grades 4 and 7, three factors were identified that may be called cognitive development, language-arts concept achievement, and mathematics-and-science concept achievement. At grade 7, as shown in Table 1, a fourth factor was found involving the discrete

Insert Table 1 about here

cognitive ability tests. The cognitive ability factor is interpreted to be a highly specialized ability, not strongly related to the other factors, and it will not be discussed further. Similarly, the remainder of the discussion is limited to the results in grade 7. We may now deal in more detail with the cognitive development factor and return to the language-arts achievement factor and the mathematics-and-science achievement factor.

Surprisingly, a single factor which we shall call cognitive development was found to underlie performance on both the levels and uses tests of all three assessment batteries. The standardized educational achievement test scores in language arts, mathematics, and science loaded on this same factor from which a hierarchy may be inferred, as shown in Figure 2. One basis for explaining the high

Insert Figure 2 about here

correlations between cognitive development and the educational achievements tested is as follows. The same mental operations, emerging developmentally and performed by students on the content as represented in the items of the concept assessment batteries, are also involved in achieving the subject matter measured by the standardized educational achievement tests. These achievement tests are not based on a particular curriculum and are more measures of educational development than of achievement of the particular subject matter taught to these groups of students. It will be recalled that the mental operations involved in the assessment batteries are attending, discriminating, remembering, generalizing, hypothesizing, evaluating, and inferring, and that the assessment batteries include figural, symbolic, and semantic content according to the Guilford (1967) scheme.

How may the cognitive development factor and the major educational development factors be related to the findings from Project Talent (Shaycoft, 1967)? Based on the Project Talent factor analytic studies involving ninth- and twelfth-grade students, a general verbal ability factor and four major group factors were found, one each in English, mathematics, spatial, and technical information (see Figure 3). As noted tests in spelling, capitalization, punctuation, English usage, and effective expression loaded on the English factor. Tests of physical science information, biological science information, and mechanics, among other tests, loaded on the technical information

Insert Figure 3 about here

(this factor might have been called a science and technology factor). We are now gathering data on ninth- and twelfth-grade students using the four concept assessment batteries and also two key tests from each of the four major factor areas identified by Project Talent to ascertain whether we get the same four factors and also whether the same cognitive development factor found as for the seventh-grade students. We hypothesize that we will.

We note that a totally different set of tests were used in Project Talent than in the present factor analytic study. Therefore, we will be unable to relate the general verbal ability of Project Talent and our cognitive development factor in a meaningful way. However, even though very different tests were used, independent researchers consistently identify major group factors corresponding to the major subject fields, as is discussed further.

Hierarchy of Concept Achievement--Cognitive Abilities

The distinct language arts and mathematics-and-science concept achievement factors identified in the present study are similar, but not identical, to those found in a series of three factor analytic studies by Harris and Harris (1973) involving fifth-grade students. In the first study, they used 120 concept achievement tests in English, mathematics, science, and social studies, of which 18 were also used in the present study. They also used 56 cognitive ability tests in another study, drawing on the ideas from Guilford's (1967) structure of intellect, Guttman's (1970) facet design of nine abilities, and

the seven primary mental abilities identified by Thurstone and Thurstone (1941). Harris and Harris found a concept achievement factor in each language arts, mathematics, science, and social studies when only the 120 concept achievement tests were administered. In the third study when only part of the concept achievement tests and part of the ability tests were administered, only two concept achievement factors were found for both boys and girls, namely science-social studies and language arts-mathematics. As shown in Figure 4,

Insert Figure 4 about here

concept achievement in science-social studies was found to be related to three abilities: verbal comprehension (comprehension of information presented in verbal- or pictorial-semantic content, including induction of classes), induction of classes (induction of classes when non-semantic content is employed), and memory; while concept achievement in language arts-mathematics was related also to three abilities: word fluency, numerical reasoning (using numbers as cardinal numbers but not as nominal symbols), and memory.

It is difficult to relate the concept achievement hierarchy to the earlier cognitive development--educational development hierarchy inasmuch as different student populations were used in the studies and only 18 concept achievement tests were common to both studies. One might conclude tentatively, however, that the abilities underlying the achievement of particular concepts in various subject

fields are more specific than those underlying educational developments in the same subject fields. Further, the number and nature of the concept achievements factors identified appear to be related both to the number of concept achievement tests administered and to the specific curricula experienced by the students.

Conclusions

The present experimental tests of conceptual development appear to be valid measures of the concept-principle-problem-solving component of mental development. This component is independent of the particular subject matter content measured both by the Stanford educational achievement tests and by our own assessment batteries. For the age range of 9 to 13, the test scores could be useful in predicting educational achievements in English, mathematics, and science over a short time period, such as a year. Factor analytic studies are yet needed involving children of both primary and high school age to ascertain the structure of cognitive and educational development across all levels of schooling.

While much work remains to be done, the present set of studies demonstrates that scales can be constructed to measure the course of cognitive development, based directly on a theory which specifies the mental operations required to attain successive levels of the same concept and also the uses that individuals can make of the concepts they have learned. Inasmuch as the cognitive development factor underlies educational developments as measured by educational

achievement tests it would appear to eliminate the need for attempting to relate educational development to any concept of intelligence. We can probably contribute more to both science and practice by abandoning the obsolescent concepts of both IQ and mental age and focusing our efforts on developing theory and measurement tools more directly relatable to our primary interests in students' achievements of what they have had opportunity to learn and in their long-term educational development across the school years in various subject fields.

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Table 1

Grade 7 Rotated UMLFA Factor Loadings and Related Ranks for 33 Variables and Four Factors (Unrestricted Maximum Likelihood Factor Analysis)

No.	Variable	Language arts		Cognitive development		Math-science		Discrete cog. abilities	
1.	Tree: Levels			60	(6)			51	(3)
2.	Tree: Uses			69	(1)	50	(10)		
3.	Noun: Levels	54	(8)	62	(5)			34	(12)
4.	Noun: Uses	39	(16)	66	(3)				
5.	Eq. Triangle: Levels			64	(4)	30	(22.5)		
6.	Eq. Triangle: Uses			68	(2)				
7.	Math: Plane			32	(17)	59	(6)		
8.	Math: Subset	60	(5)			36	(15.5)	39	(8.5)
9.	Math: Factor	46	(11)			31	(20.5)		
10.	Math: Open Sentences	45	(12)	33	(15)	34	(19)		
11.	Math: Numerator					54	(8)	36	(11)
12.	Math: Place Value	31	(22.5)			51	(9)	43	(7)
13.	Math: Eq. Triangle	42	(15)			43	(12)		
14.	Science: Cell	33	(20.5)			39	(13.5)	45	(5.5)
15.	Science: Invertebrate					61	(5)		
16.	Science: Moon	33	(20.5)			66	(3.5)		
17.	Science: Condensation	43	(13.5)	34	(12)	68	(1.5)		
18.	Science: Sedimentary Rock	34	(18.5)	33	(15)	66	(3.5)		
19.	Science: Expansion	36	(17)	35	(10)	68	(1.5)		
20.	Science: Tree					55	(7)	49	(4)
	Language Arts:								
21.	Suffix	65	(3)			39	(13.5)	38	(10)
22.	Adjective	69	(2)	33	(15)				
23.	Predicate	77	(1)			35	(17.5)		
24.	Heading	52	(10)			35	(17.5)		
25.	Topic Sentence	64	(4)						
26.	Synonym	59	(6)	34	(12)				
27.	Noun	53	(9)			48	(11)	39	(8.5)
28.	SAT: Capitalization			53	(7.5)			45	(5.5)
29.	SAT: Math.	43	(13.5)	53	(7.5)	31	(20.5)	33	(13)
30.	SAT: Science	37	(7)	46	(9)	36	(15.5)		
31.	Cog. Class Name Select.	34	(18.5)			30	(22.5)	62	(1)
32.	Cog. Verb. Class.							61	(2)
33.	Cog. Fig. Exclusion	31	(22.5)	34	(12)			31	(14)
	% of Total Variance	18.8		15.1		17.7		11.0	

Note--Only loadings above .30 in absolute value are reported.
Based on Rampaul, 1976, pp. 64-65.

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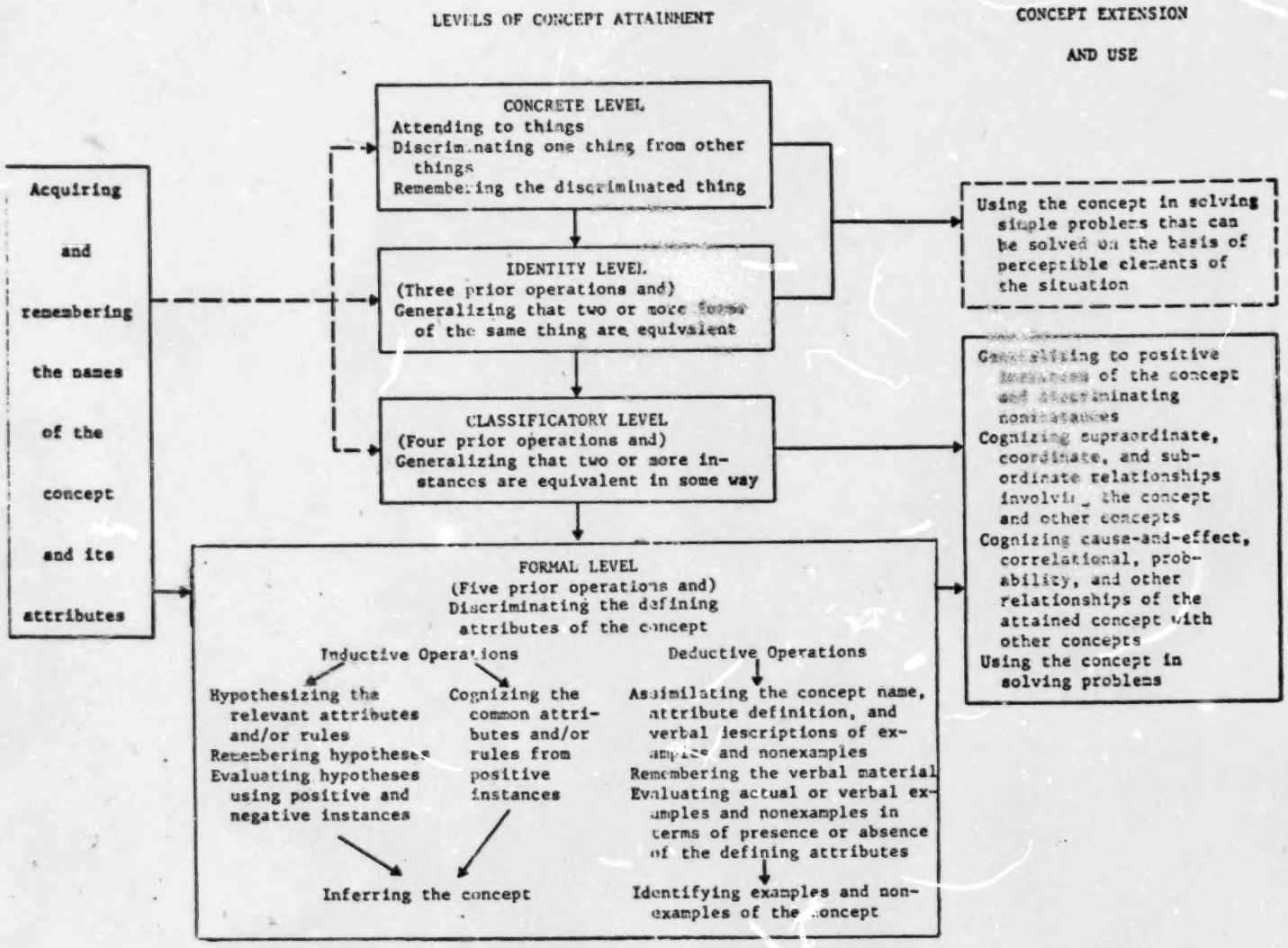
LEVELS OF CONCEPT ATTAINMENT
CONCEPT EXTENSION AND USE
Acquiring and remembering the names of the concept and its attributes
CONCRETE LEVEL
Attending to things
Discriminating one thing from other things
Remembering the discriminated thing
IDENTITY LEVEL
(Three prior operations and)
Generalizing that two or more forms of the same thing are equivalent
CLASSIFICATORY LEVEL
(Four prior operations and)
Generalizing that two or more instances are equivalent in some way
FORMAL LEVEL
(Five prior operations and)
Discriminating the defining attributes of the concept
Inductive Operations
Deductive Operations
Hypothesizing the relevant attributes and/or rules
Remembering hypotheses
Evaluating hypotheses using positive and negative instances
Cognizing the common attributes and/or rules from positive instances
Assimilating the concept name, attribute definition, and verbal descriptions of examples and nonexamples
Remembering the verbal material
Evaluating actual or verbal examples and nonexamples in terms of presence or absence of the defining attributes
Inferring the concept
Identifying examples and nonexamples of the concept
Using the concept in solving simple problems that can be solved on the basis of perceptible elements of the situation
Generalizing to positive instances of the concept and discriminating noninstances
Cognizing supraordinate, coordinate, and subordinate relationships involving the concept and other concepts
Cognizing cause-and-effect, correlational, probability, and other relationships of the attained concept with other concepts
Using the concept in solving problems

Figure 1. Cognitive operations and concept learning. (Based on Klausmeier, Ghatala, & Frayer, 1974.)

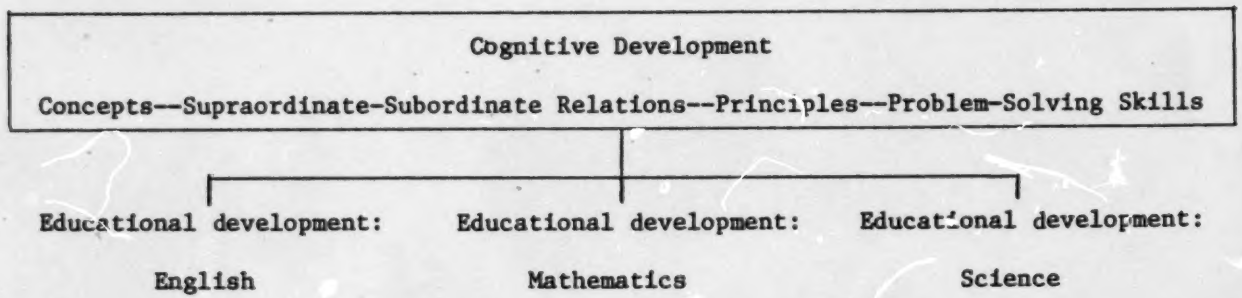

Figure 2. Hierarchy of cognitive development-educational development.

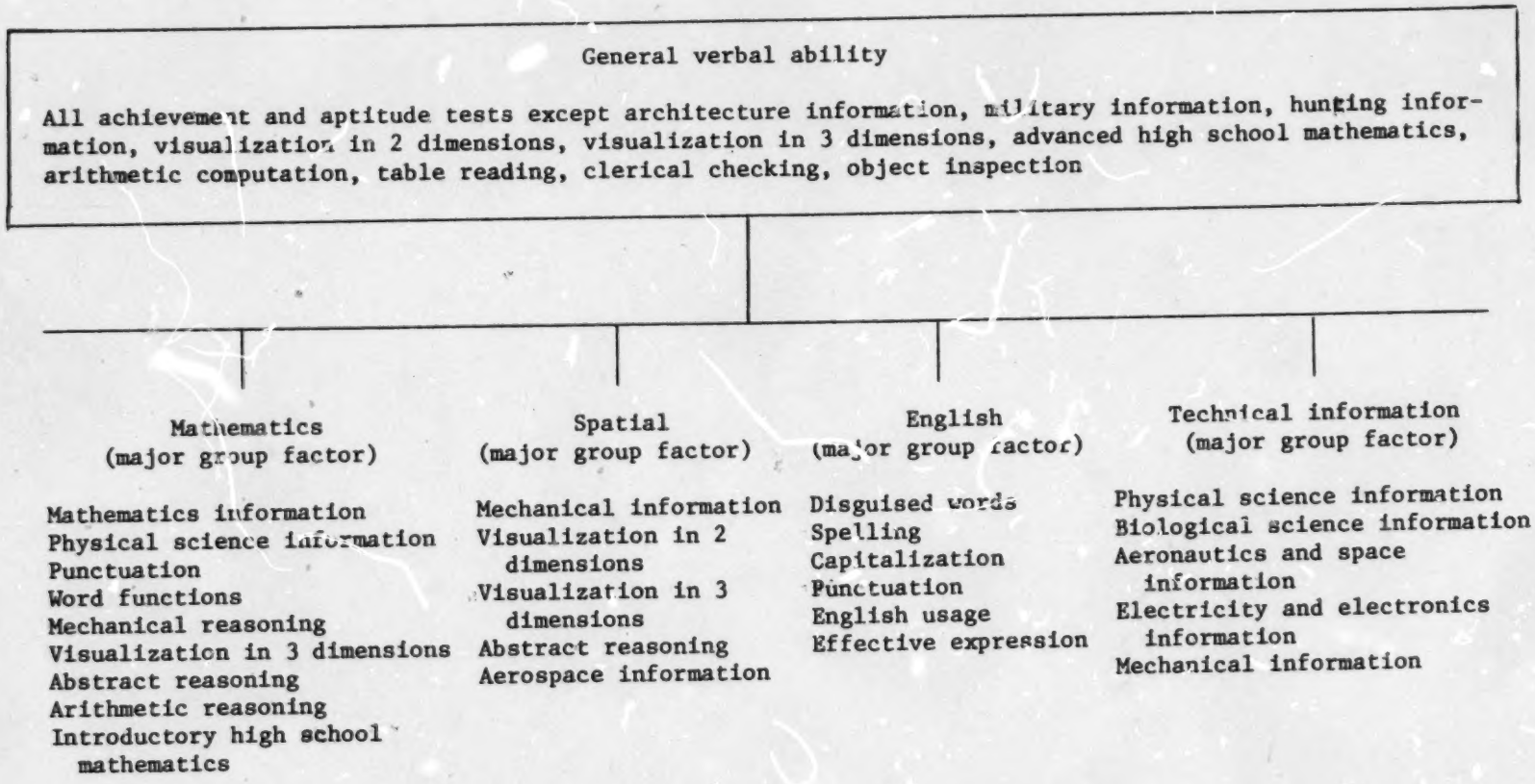

Figure 3. General and major group factors common to grades 9 and 12 and to boys and girls (Identified by Shaycoft, 1967).

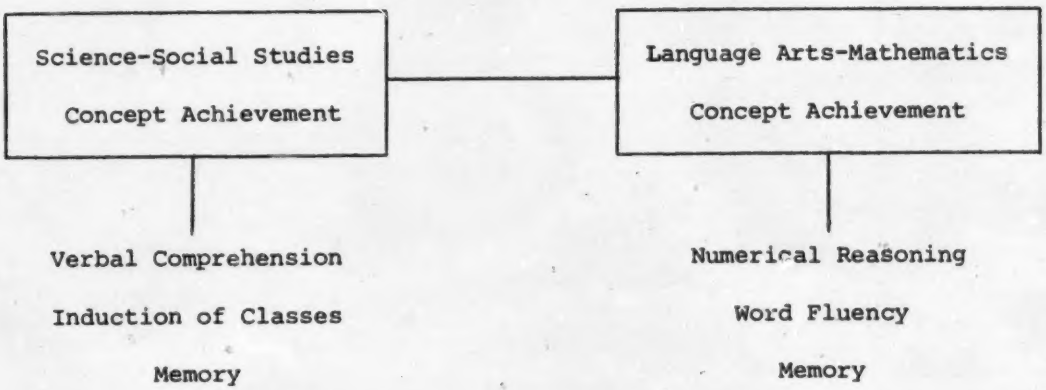

Figure 4. Hierarchy of concept achievement factors and primary mental abilities identified by Harris and Harris (1973, p. 195).